Improving the Effectiveness of Water for Fire Fighting

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INTRODUCTION

Fire is of great benefit to mankind. It furnishes the heat for his cooking and for warmth of his shelters. Until the relatively recent advent of nuclear power, some form of combustion process, that is fire, provided the major source of energy for his power.

However, along with its tremendous value, fire has also proved a terrible enemy of mankind. Few people need to be convinced of the heavy annual waste resulting from uncontrolled fires in the civilized world, as well as in areas where civilization has progressed more slowly.

Uncontrolled fires have caused frightening physical, mental and financial losses to local communities. For example, from 1948 to 1952, the average annual fire loss according to the National Fire Protection Association in the United States amounted to $814,957,000. Even this figure cannot possibly take into account the lost lives, the destroyed businesses and the disruption of production.

This paper discusses a new method to help mitigate this terrible toll of fire waste. Ideally, the best way to combat the problem of fires is to prevent them. Unfortunately, this approach appears to be one of the most difficult to implement. Another way to combat this problem is to increase the rapidity with which fire extinguishing agents function.

Research scientists in fire fighting are constantly working toward this goal. If an improved extinguishing agent can be developed, the fire loss can be decreased. Scientists at Syracuse University have been working toward such a goal for the past fourteen years. From 1947 to 1957, the primary concern was with methods to increase the effectiveness of fire fighting foams. During the past four years, these researches have been concentrated on methods to improve the fire fighting characteristics of water.

The original fire research conducted at Syracuse University dealt with fire fighting foams. The major objectives during this work were to develop better foam formulations, foam generation techniques and foam extinguishing systems. These studies were largely carried out under the auspices of the Navy and Army. Early experimental work was partially responsible for the development of the high expansion foam used to envelop an aircraft crash fire. Other uses of foam in air disasters are for covering a runway for a "belly landing", blanketing a gasoline spillage to prevent fires from starting, and even for calming wave action in sea rescue operations. Syracuse University conducted much of the fundamental research on these uses, while the government facilities were concentrating on pertinent applications. Foams are probably the best methods available for extinguishing Class B fires.

During this work there was also some experimentation with the extinguishment of Class A fires which are normally attacked by water. The studies on foams led to the belief that some of their outstanding qualities, such as blanketing ability and high viscosity, might be obtainable in water through the use of certain additives. The present study was thus initiated to determine whether additives improve the fire fighting characteristics of water, and if so, which formulation is most effective.

Water in its natural state has been used to extinguish fires for many centuries. It has three great advantages because of its cooling properties, low cost and almost universal availability. Before the great trend toward urbanization in the United States and other parts of the world, these three qualities were sufficient to offset some of the limitations of water as a fire fighting agent. However, today when a city fire is feared not only because of the damage inflicted to one building but also because of the possibility of damage to a great area, these limitations can not be completely neglected. There is also a further danger that with the current population explosion, the supply of water may be extremely limited in some areas.

The limitations of water are essentially three fold. First, because of its low viscosity, water forms a thin film which rapidly runs off the burning structure. This may allow the fire to reignite. Secondly, water's continued blanketing ability is limited. Third, water has relatively poor reflective powers. If the radiant energy of the fire can be separated from the source of fuel, more rapid extinguishment of the flame is possible. The reflection of the radiant energy away from the adjacent buildings will help to prevent the spread of the fire.

EXPERIMENTAL PROCEDURE

The approach to this problem has been to prepare solutions of various additives and water and to test these new solutions for fire fighting effectiveness. Basically, the experimentation has been with two major groups of additives: viscosity additives and opacifier additives. Detergents have been used in limited amounts to improve the initial spreading of the viscous water. Viscosity additives are utilized to improve the blanketing and run-off properties of water. The opacifier additives are employed to reflect radiant energy away from the burning and/or adjoining structures.

Work to date has been primarily directed toward the evaluation of viscosity additives and these additives have generally been the most effective. However, experience with opacifiers has also been accumulated. Samples have been received from many major manufacturers of viscosity, opacifier and detergent additives. Essentially, the basic approach is to screen these additives in the laboratory and then test the more promising ones on small and large scale fires.

The viscosity additives, are tested on a run-off simulator apparatus (ROSA) which was designed and built in the Syracuse University laboratories. This apparatus was designed to simulate the actual run-off properties of the fire fighting solution. It measures the fluid film time, temperature drop, and volume of the liquid evaporated.

The more promising additives are subjected to a small scale fire test. All small scale fire tests are conducted in a small laboratory built expressly for this purpose. The test site itself is constructed such that the tests can be conducted in a controlled environment. Such variables as rain, snow and wind velocity do not affect the test conditions (7). Both the small and large scale fire tests are conducted in an enclosed fire room. This room consists of a Butler building which is approximately 13' x 12' x 12' and which is constructed of galvanized sheet metal. A window has been inserted on one side of the enclosure so that the performance of the solution as it is sprayed on the burning surface can be observed. Exhaust facilities have been provided to permit adequate control of ventilation or draft.

The fuel generally used for both large and small scale fires is California clear pine which has been presoaked in kerosene, for approximately 30 seconds. For the small scale tests, eight pieces of the wood, 1" x 3" x 10", are arranged in two tiers. A single nozzle (Fulljet 1/8 GG8, manufacturered by Spraying Systems Company) is located at the height of 6 feet above the fire. The wood is ignited and the fire is allowed to burn four minutes before extinguishment is started. Through use of thermocouples and a radiometer, it has been found that almost all of the test fires reach their maximum intensity at this time interval. In studying the effect of viscosity on extinguishment, a uniform preburn time of four minutes was used. On the small scale fire test, the sample solution was sprayed on the burning structure at a rate of 1.G.P.M.

After the various solutions of additives are tested on the small scale fires, the surviving promising ones are further tested on larger scale fires. In this test the wood, which is 2" x 4", is arranged in three tiers. The first tier is comprised of 13 pieces each 36" long spaced one inch apart. The second tier is comprised of 12 pieces each 35" long, and the top tier consists of 12 pieces each 34" long. This is shown in Figure 1. Thus, a type of truncated pyramid structure is obtained. Only the wood in the first tier is presoaked in kerosene. In this test, four nozzles (Fulljet 1/4 GG nozzles, manufactured by Spraying Systems Company) are used for extinguishing the fire. The nozzles are equally spaced at a distance of 1.4 ft., from the center of the fire crib, and approximately 12 ft., above the wood arrangement. In the larger scale fire tests, varied preburn times are used but the sample solution is sprayed on the burning structure at a rate of 3.6 G.P.M., 19 psi.

After ignition, the intensity of the large scale fire continually increases until it reaches a maximum after about three minutes. (Figures 2 and 3). The preburn times for the large scale fire tests are varied in order to permit thorough analysis of the effects of various additives on extinguishment. Each formulation is tested on the larger scale fire and the results are compared with corresponding data obtained using water alone.

Recent work has been concentrated on transferring the optimum formulation results from the laboratory to field fire tests. In these efforts, local county fire departments have cooperated. Several series of field fire tests have been run in cooperation with the Navy Fire School at Norfolk, Virginia on cribs of seasoned 2" x 4" pine wood, measuring approximately 8 feet on a side and 4 feet in height.

In addition to these relatively controlled tests, close liaison has been maintained with the U. S. Department of Agriculture, Forest Service, Division of Forest Fire Research, Berkeley, California. Mr. Carl C. Wilson, Chief of the Division, and associates ran operational studies in the summer of 1960 and are running additional operational studies at this time utilizing viscous water on some of the tank fire trucks for fighting forest fires.

RESULTS AND DISCUSSION

Studies to date have yielded some quite significant results. A number of viscosity increasing additives have been found which improve the effectiveness of water as a fire fighting agent. Some additives are more effective than others. Opacifiers have been shown to decrease the radiant energy transfer. Further study on opacificers has been delayed since over 75% of the total improvement was attributable to increased viscosity. Viscous water without opacifiers offers less attendant storage problems.

(a) Initial Control: One of the important factors in fighting Class A fires is the "knock-down" or initial control. This is a very difficult parameter to measure quantitatively due to the differences in fire fighting personnel and procedures. However, experience in the laboratory fire tests (Figure 4) and in the field fire tests has shown that viscous water "knocks down" the fire much more rapidly than plain water. The fire fighters can advance up to or into the structure for rapid control and later for final "clean-up". As a further advantage, more rapid initial control means less fire damage and in some cases, preserves life.

A rather vivid illustration of this phenomenon was reported (1) from some tests run by the Los Angeles City and County Fire Departments at the Van Nuys, California Airport. "A previously exposed building was ignited and one room allowed to become completely involved. The fire was then knocked down in 15 to 20 seconds with viscous water at an application rate of 30-40 G.P.M. The demonstation was repeated several times. Finally, the building was allowed to burn until it was completely involved and about half of the roof had caved in. At this point one of the Los Angeles City Mountain Battalion Crews attempted to extinguish it. They used a small pumper with a capacity of about 35 G.P.M. They made little, if any, progress and gave up after one of the firemen received minor burns. The viscous water crew next took over with about the same application rate and were able to knock the fire down and bring it under control in about four minutes".

(b) Extinguishment Time: Small fire tests were conducted on cribs consisting of eight pieces (1" x 3" x 10") of California clear pine arranged in two tiers, four pieces in each tier, with one inch spacing. The viscous water was applied at a rate of one G.P.M. after a preburn time of four minutes. The extinguishment time decreases as the viscosity is increased. Figure 5 illustrates this effect by two different viscosity additives, Monsanto DX-840-91 and bentonite clay, Volclay (2). Volclay reaches its peak of effectiveness at a viscosity of five centipoises, while Monsanto DX-840-91 reaches its peak at ten centipoises. The reason for this difference is not fully explainable.

Larger scale fire tests were run as previously described. The results (3) of a series of tests comparing extinguishment time for water and for viscous water, obtained from the addition of Dow ET-460-4 are shown in Figure 6. Certain uncontrollable variables, such as the chemical and physical properties of the wood and the difficulty of obtaining a perfectly reproducible test fire, cause a scattering of the data. However, it can be clearly seen that the use of viscous water gives a marked reduction in extinguishment time when plotted as a function of minutes of preburn time. For example, at a preburn time of four minutes, water took about 8 minutes for complete extinguishment, while viscous water (5.5 cp.) averaged about 1 1/2 minutes. With water, the wood collapsed during extinguishment for a preburn time of five to six minutes. On the other hand with viscous water, extinguishment was so rapid that it was possible to obtain preburn times of as much as nine minutes, with no wood collapse. Other additives for increasing viscosity, e.g. sodium alginates, were tested with results of the same general magnitude.

The results on extinguishment time for Dow ET-460-4, Carboxymethyl Cellulose (CMC) and water are shown in Figure 7, with preburn time as a parameter. Each viscosity additive reduces extinguishment time, although at the same viscosity Dow ET-460-4 appears to be more effective than CMC.

Field fire tests at the Navy Fire School in Norfolk have confirmed the reduction in extinguishment time when viscous water is used. The percentage reduction is not as marked as in the laboratory but control and reproducibility of open field fires are much more difficult; scatter of data is wide.

Based upon laboratory results, fire fighting agencies in California and Nevada pooled their efforts in 1960 to conduct a series of suppression and retardant tests to determine whether the chemical additives could be used to help control forest fires with ground equipment. A report (5) on this effort from the U. S. Department of Agriculture, Forest Service, Division of Forest Fire Research states: "Viscous water reduced suppression time under many conditions and was outstanding in keeping fires from rekindling. The residual film of algin thickened water seemed to be particularly effective in extinguishing usually difficult-to-extinguish fires in fuels such as baled hay and sawdust. Although there were operational difficulties such as spoilage and slight corrosion of metal parts, most problems have or can be solved. The dry powder that makes the water thick can be mixed on the fireline in 1 to 5 minutes using the jet-type mixer which is easily installed on the truck".

(c) Reignition: A common problem in Class A fire fighting is the reignition of the fire after it has been extinguished, due to the residual heat. Many such experiences have been presented in fire fighting annals. One of the outstanding characteristics of the viscous water extinguishment is the almost universal lack of reignition after the fire is "out". This is quite evident in the controlled laboratory test fires. A large number of detailed tests have been reported (3,4) which show that fires extinguished with water reignited from one to four times after initial extinguishment, while most of the comparable fires extinguished with viscous water did not reignite. It was also quite evident that water extinguished fires retained much more residual heat, necessary for reignition, than viscous water extinguished fires.

Comparable results on reignition have been observed in various field fire tests at Norfolk and at Mariposa Airport, California. Reignition occurs at times even with extinguishment with viscous water; however, it is much delayed and is more easily controlled. Davis (6) stated in regard to the Mariposa Airport tests: "The chemicals also had a noticeable effect on rekindling of the charred cribs that remained after the initial suppression. Although cribs sprayed with viscous chemicals did reignite, rekindling was slower in starting and cribs that rekindled, burned at a lower rate than those sprayed with water".

(d) Reduced Water Consumption: In many tests, it has been shown that the rate of extinguishment with viscous water is many times greater than with plain water. This means that a given fire can be fought with reduced water consumption; the water actually used is much more effective. While in many parts of the world, water is available in unlimited quantities for fighting fires there are many other places on the globe where water is very scarce. A good example of this is Southern California.

Where fires need to be fought in isolated places and all fire fighting water must be brought in by trucks, it becomes of grave importance to utilize fully every bit of water. If one assumes a five fold increase in rate of extinguishment for viscous water, it is easy to see that one tank truck of viscous water can control as much fire as five tank trucks of plain water.

(e) Reduced "Run-Off": An obvious disadvantage of poor utilization of water is the rapid "run-off" so that only a portion of the water is effective. A large number of laboratory fire tests have shown that viscous water is more effectively used for extinguishment. A group (3) of comparative tests were run to check this point under controlled conditions. Plain water applied at a rate of 3.6 G.P.M. averaged three pounds per minute of "run-off"; for CMC at a viscosity of 5.5 cp., the "run-off" was only 1.5 pounds per minute; and for Dow ET-460-4 the rate was less than 1 pound per minute of 5.5 centipoise viscous water.

A corollary to the more effective use of viscous water is the reduced water damage to structures, contents, and adjoining facilities. Every one recalls the large fire several years ago in lower New York, in which the old Wannamaker store building was destroyed, but, does every one recall that the adjacent subways were flooded out of service for many hours? Frequently, firemen complain that water damage to the contents of a structure is as great as the fire damage.

(f) Logistics of Chemical Additives: The amount of chemical additives required to achieve an optimum viscosity of water for fire fighting varies with the characteristic of the chemical. Satisfactory viscosity can usually be achieved with less than 0.2% of a chemical additive. This percentage would require about 16 pounds for treatment of 1,000 gallons of water.

Some of the chemical additives are only in pilot plant production, so costs per pound are not firm. Others, such as CMC and Keltex FF, are in full production. At a price of $0.50 per pound for chemicals, it would cost less than one cent per gallon to raise the viscosity of the water to a satisfactory point. This would not be considered prohibitive under many conditions of fire fighting.

Davis and Phillips (5) state that for fighting forest fires even a higher cost per gallon for chemical additives is not prohibitive. "The price per gallon is reasonable for all of these chemicals, only 3 to 14 cents per gallon".

CONCLUSIONS

1. Viscous water produces much more rapid initial control of Class A fires.
2. The rate of extinguishment of Class A fires is more rapid with viscous water.
3. The danger of reignition is markedly reduced when Class A fires are extinguished with viscous water.
4. A lower amount of viscous water is required for extinguishment of Class A fires.
5. Markedly reduced "run-off" of viscous water mitigates water damage.
6. Logistics of chemical additives for fire fighting is economical.

LITERATURE CITED

1. Davis, J. B., Private Communication, United States Department of Agriculture, Forest Service, Division of Forest Fire Research. (March, 1961)
2. Aidun, A. R., "Additives to Improve the Fire Fighting Characteristics of Water", Quarterly Progress Report No. 9, Contract No. NBy 13027 (October, 1959).
3. Ibid., Quarterly Progress Report No. 11 (April, 1960).
4. Ibid., Quarterly Progress Report No. 12 (July, 1960).
5. Davis, J. B. and Phillips, C. B., "Fire Fighting Chemicals -- New Weapons for the Fire Suppression Crew", Pacific Southwest Forest and Range Experiment Station, Research Note No. (In press), 1961.
6. Davis, J. B., Private Communication, United States Department of Agriculture, Forest Service, Division of Forest Fire Research. (October, 1960).
7. Grove, C. S. Jr., "Methods to Improve the Fire Fighting Characteristics of Water", Proceedings of the Sixty Fourth Annual Meeting of the National Fire Protection Association, Page 38 (May 16-20, 1960).

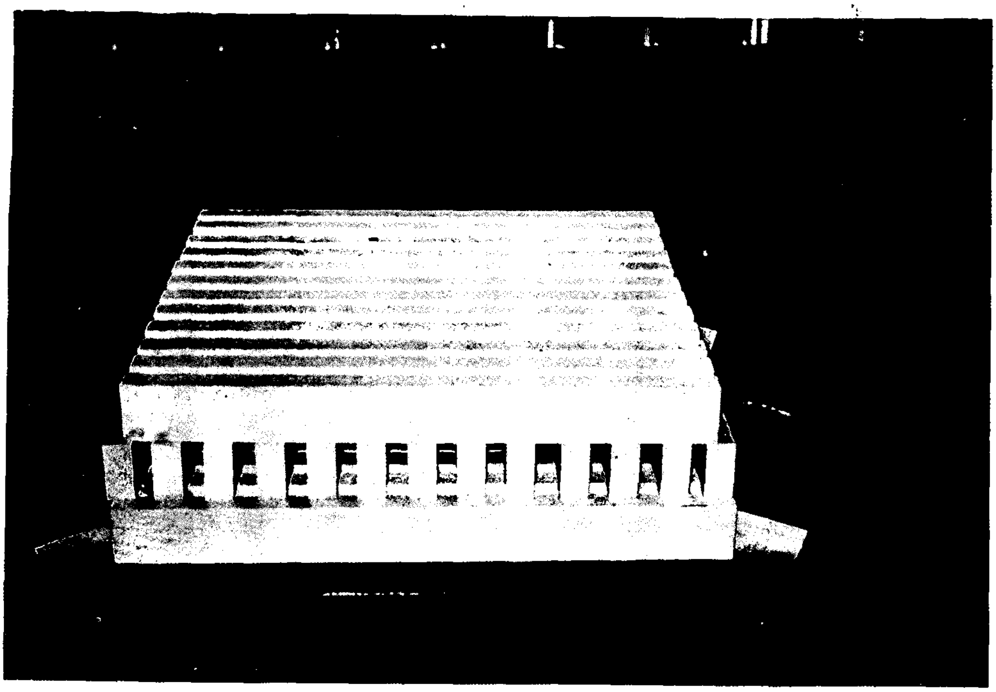


Figure 1

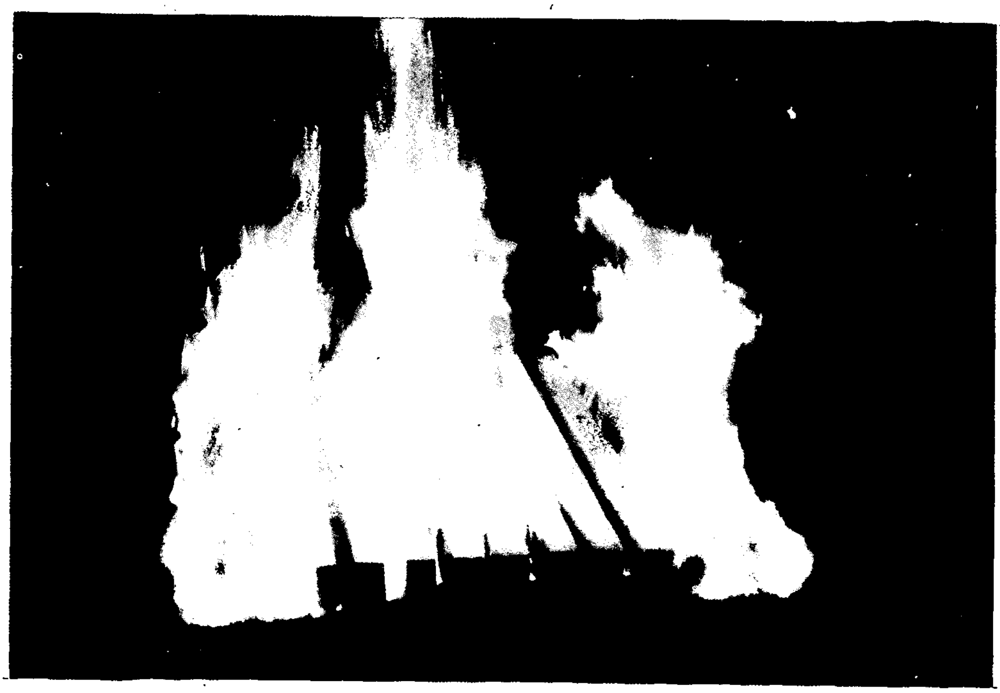


Figure 2

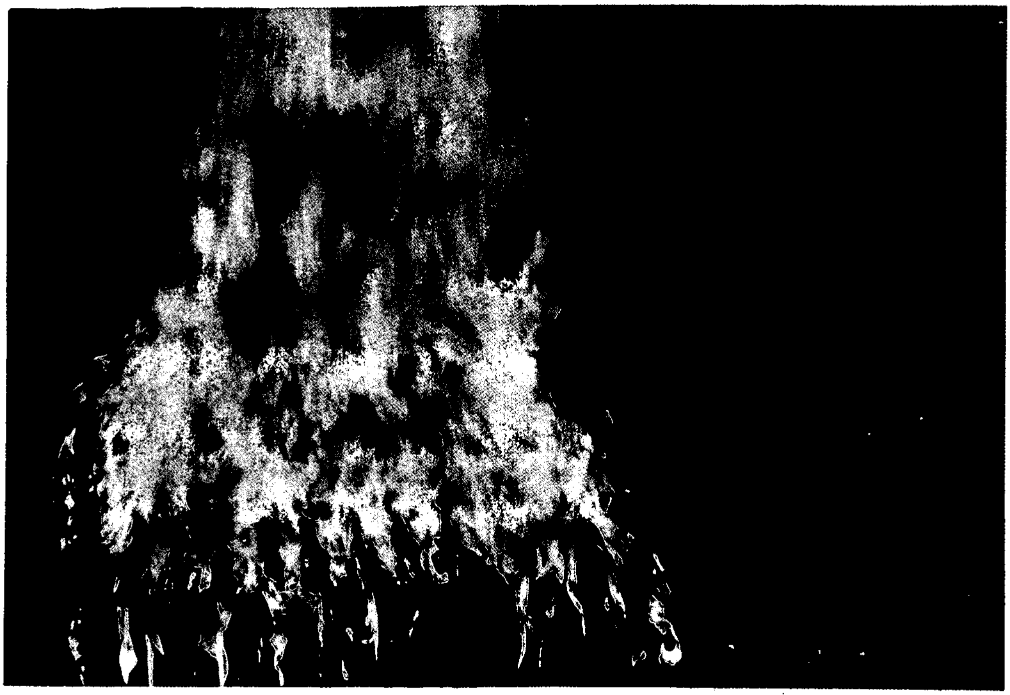


Figure 3

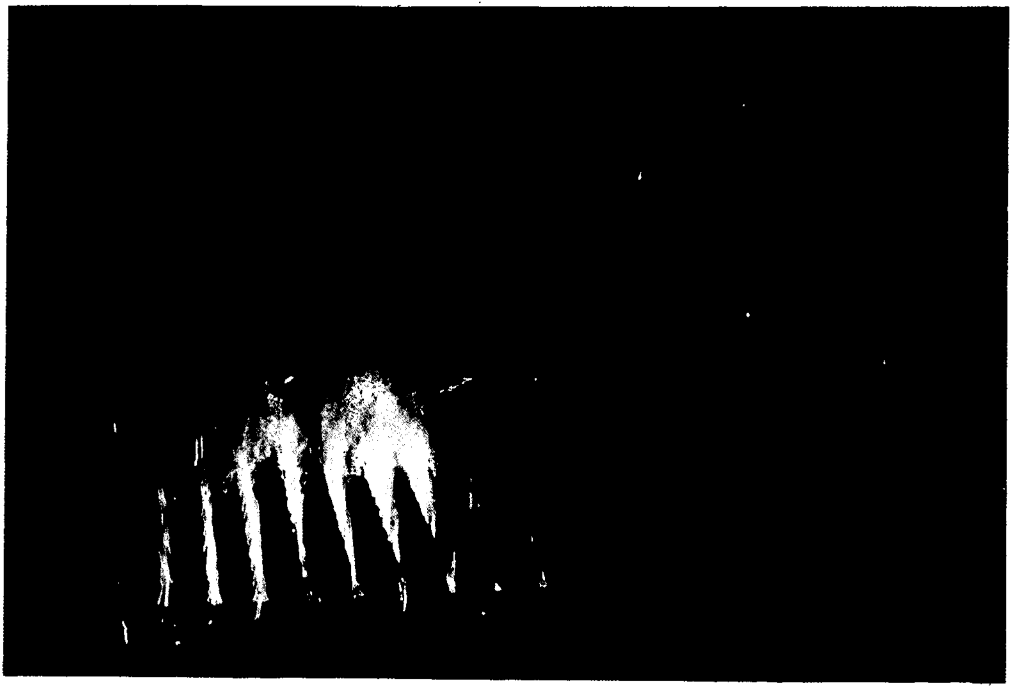
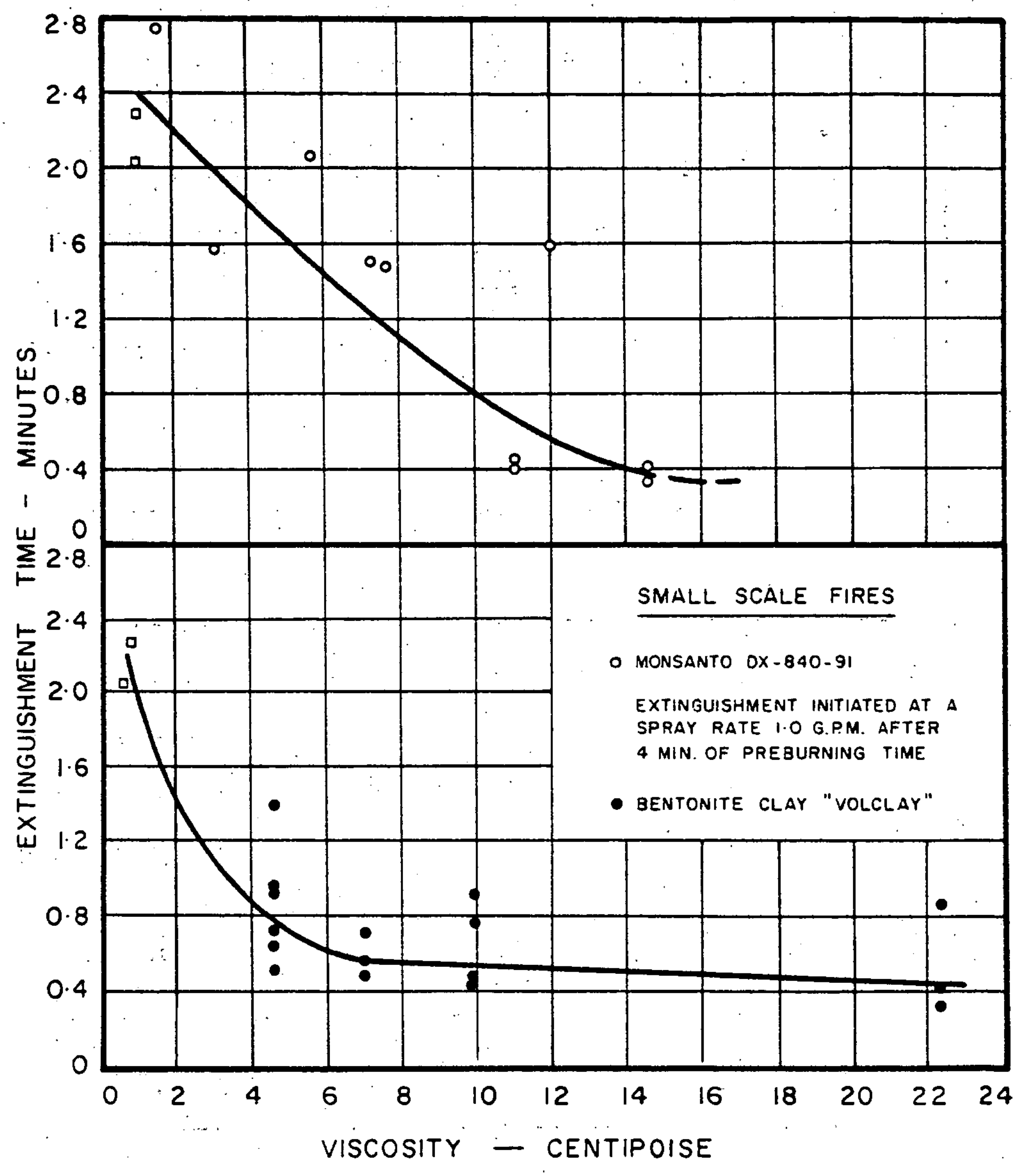
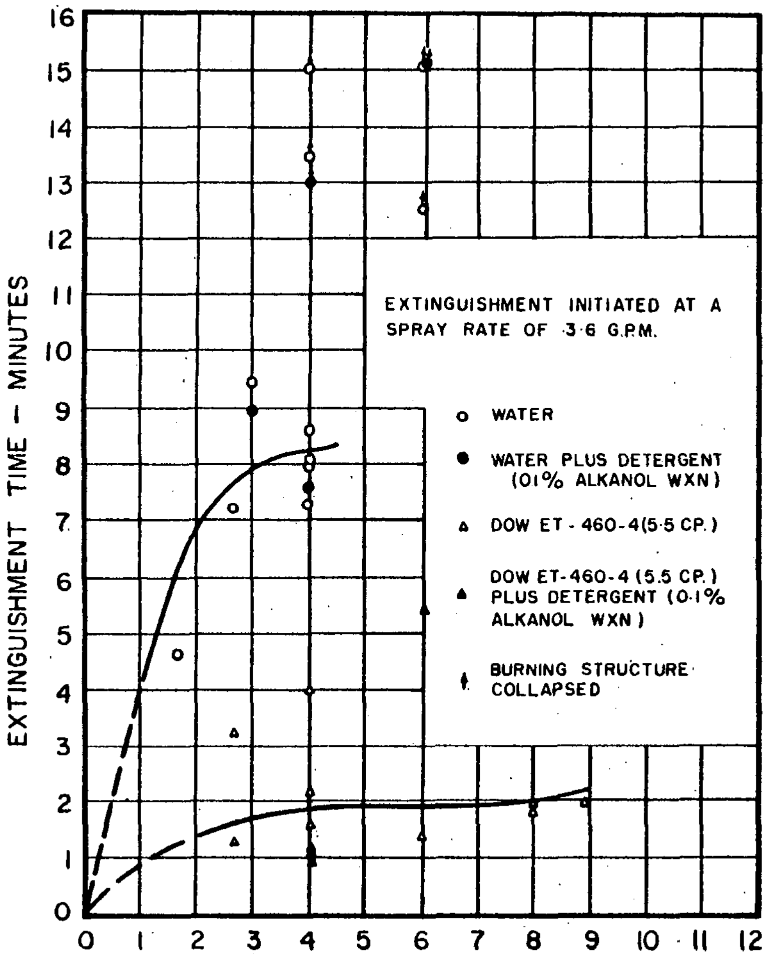


Figure 4



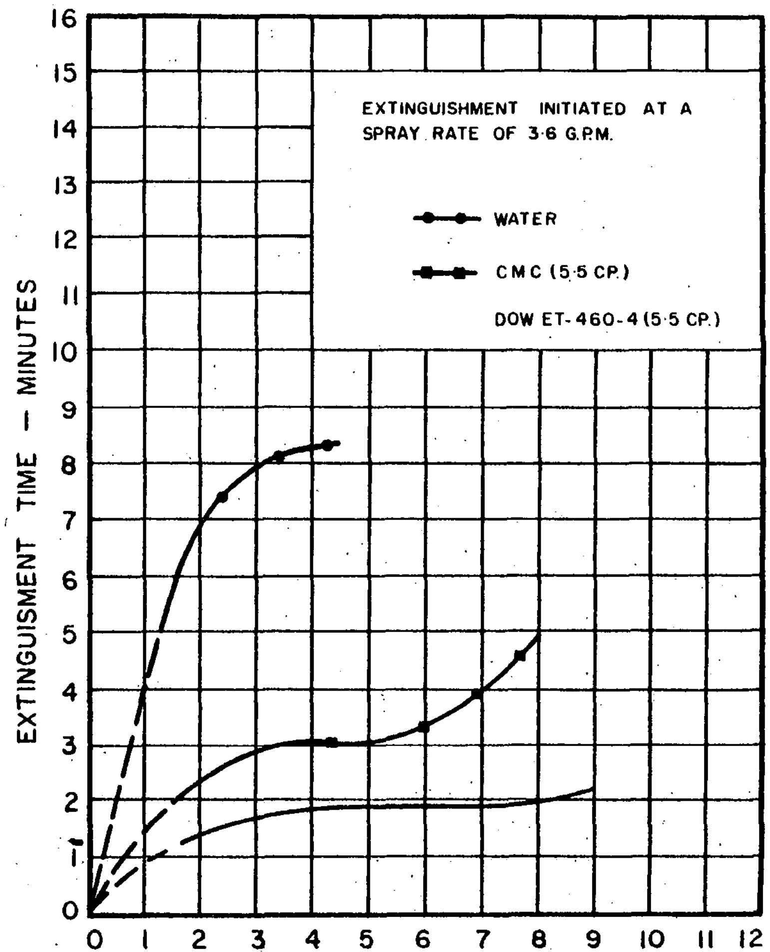
EXTINGUISHMENT TIME VS PREBURN TIME

FIGURE 5



EXTINGUISHMENT TIME VS PREBURN TIME

FIGURE 6



EXTINGUISHMENT TIME VS PREBURN TIME

FIGURE 7